MEDICINAL PROPERTIES OF PLANTS USED IN TRADITIONAL MEDICINAL SYSTEMS

Abstract

Traditional medicinal systems have a long history of utilizing plants for healing purposes, drawing upon centuries of indigenous knowledge and experimentation. This chapter explores the diverse medicinal properties of plants used in traditional medicine worldwide. Beginning with an overview of the holistic principles that underpin traditional healing, including the interconnectedness of mind, body, and spirit, alongside emerging nanotechnology applications, the chapter then categorizes medicinal plants based on their various therapeutic properties, including anti-inflammatory, antimicrobial, analgesic, and antioxidant activities, among others. Drawing from both ethnobotanical knowledge and scientific research, specific plant species celebrated for their medicinal efficacy are highlighted, showcasing their traditional uses and evidence-based therapeutic applications. Moreover, the chapter delves into the mechanisms of action through which bioactive compounds within these plants exert their medicinal effects, providing insight into their interactions with biological targets. It emphasizes the importance of preserving traditional knowledge while integrating it with modern scientific methods to validate and enhance the therapeutic potential of medicinal plants. In conclusion, the chapter underscores the invaluable contribution of traditional medicinal systems to global healthcare and advocates for the ongoing exploration and conservation of plant-based remedies to address contemporary health challenges. Collaboration between traditional healers, scientists, and healthcare professionals is highlighted as a means to integrate the wisdom of nature into comprehensive healthcare solutions.

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Overall, this chapter provides a concise overview of the medicinal properties of plants in traditional medicine, bridging traditional wisdom with modern scientific understanding to promote health and well-being.

Keywords: "Ayurveda, Medicinal Plants, Traditional Medicinal Systems, Bioactive Constituents, Nanotechnology.

I. INTRODUCTION (PHARMACOLOGICAL APPLICATIONS OF HERBAL COMPOUNDS)

Across the world, plants are used as important natural resources for both traditional and contemporary medical systems. Plants and derivatives of plant products are being utilized for medical purposes for a long time. Ancient writings at Babylonia, Rome, China, Greece, Egypt and some other places have been preserved that discuss the therapeutic effects of plants. Earlier writings during 370-287 BC by Theophrastus, 384-322 BC by Aristotle, 460-370 BC by Hippocrates, and 50-100 AD by Dioscorides show that Greeks and Romans were aware of many of the botanical medicines used today. All across the world, plants have been used as important natural resources for both traditional and contemporary medical systems. Many ancient writings from Babylonia, Egypt, China, Greece, Rome, and other places have been preserved that discuss the therapeutic effects of plants. Hippocrates during the period of 460–370 BC, Theophrastus during 370–287 BC, Aristotle in the year 384–322 BC, and Dioscorides during 460–370 BC are earlier authors who wrote on medicine (50-100 AD) show that Greeks and Romans were aware of many of the botanical medicines used today. The "Ebers Papyrus," the most famous Egyptian manuscript containing a list of nearly 700 medications, dates back to 1500 BC. The earliest herbal documentations found in China date back to Erh-ya (300 BC), Svu-ching (1000 BC), and Ben-tsao (1250 AD) and mention more than 600 therapeutic plants [1]. The clay tablets from Mesopotamia (1700 BC) contain the oldest descriptions of the use of plants in Asia. Ancient Indian scriptures such as the Charka Samhita during the period of 100–800 BC, the Sushruta Samhita during 800–700 BC, the Rigveda in around 1400–1800 BC, and the Atharvaveda in 4500–2500 BC all include descriptions of herbal medicines and medical preparations. The primary source of Vedic knowledge for comprehending the curative powers of plants dates back to 1000 BC and is known as Ayurveda. The earliest written accounts of plant use in Asia date back to 1700 BC and are recorded on clay tablets from Mesopotamia. In ancient Indian literature including the Charka Samhita during 100–800 BC, the Susruta Samhita during 800–700 BC, the Rigveda during 1400–1800 BC, and the Atharva-veda during 4500–2500 BC, the herbal treatments and medical preparations were also discussed. The main body of Vedic knowledge for comprehending the curative qualities of plants is Ayurveda (ca. 1000 BC) [2]. Siddha and Unani are two additional traditional medical systems that provide information about plant-based medicines utilized in India additionally to Ayurveda. The "Unani" medical system, which had its origins in Greece was sent to India once the maritime passage to that nation was found by the Arabs and Persians. Between the eleventh and fifteenth centuries, in southern India, the "Sidda" medicine, which is comparable to the Ayurvedic system of medicine, was created [3].

1. Background and Rationale for the topic

The background of the topic futuristic trends in herbal medicine/agriculture engineering & food sciences of understanding that the herbal remedies are frequently employed for managing chronic ailments and enhancing overall well-being. An increasing number of individuals are resorting to traditional solutions when modern medical treatments prove inadequate in effectively managing illnesses, particularly in cases of advanced cancer stages and newly emerging infectious diseases. Nowadays, the plant based phytoconstituents having pharmacological, nutraceutical properties as well as they were used in agriculture for production of well-being crops. As we know that the plant sources or herbal medicine typically have been wide used in traditional medicine system from earlier time but nowadays, we have to focus on the phytoconstituents which are present in it because they are used in treatment of various disease and disorders with the less side effects. So we can say that herbal medicine will be used in future to treatment of various disorders due to their pharmacological properties and having minimum side effects.

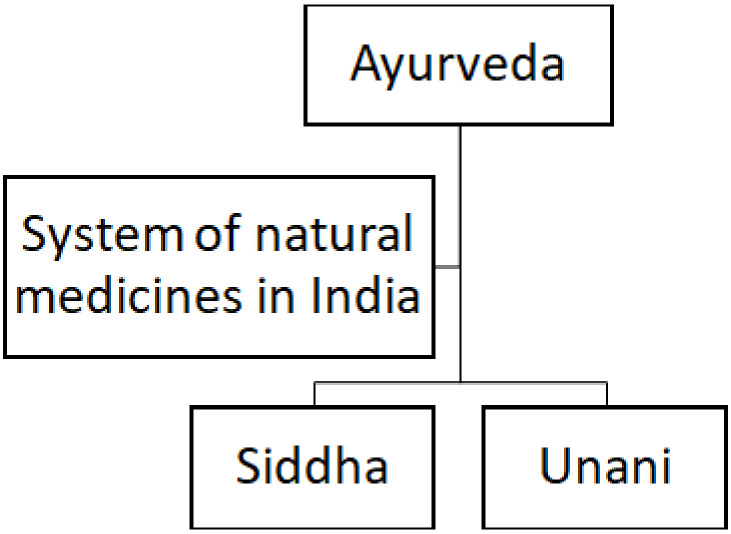

Figure 1: Natural and Herbal medicinal system used in India

According to WHO, the usage of conventional medicine is "the knowledge, skills, and practices based on the theories, beliefs, and experiences indigenous to different cultures, used in the maintenance of health and in the prevention, diagnosis, improvement, or treatment of physical and mental illness."[4]. Conventional medicines come in a wide variety, and each one's philosophy and techniques are formed by the unique local conditions, environment, and historical background [5]. A common concept, however, emphasizes harmony between the environment, the body, and the mind, a comprehensive approach to life that prioritizes health over disease. Many traditional medicinal systems rely heavily on the usage of herbs, and the patient's overall health is usually prioritized over the specific ailment or condition they are suffering from [6, 7, 8, 9].

2. Objectives and Key Questions

This chapter's goal is to give a general review of the futuristic trends of the herbal plants in medicines, agriculture and food technology. As we came to know these herbal plants having nutraceutical properties as well as pharmacological properties for the treatment of various disease and disorders as we mentioned in this chapter. Using conventional medicine has spread outside underdeveloped countries over the past 20 years, as ethnobotanicals have become more popular and interest in natural cures has increased there. As we know that many people also believe that traditional remedies are organic, risk-free, and non-toxic. So, we can say that the herbal medicines will be used in future for management of various disease due to their pharmacological, nutraceutical property and their used in food science.

- **Key Questions**

  - Write the history of herbal medicine.
  - Write the popular polyherbal remedies which are used in Ayurveda, Unani, and Siddha medicine to treat various chronic illnesses.
  - Write the pharmacological properties are shown by herbal plants with their specific parts.
  - Write the classification of phytoconstituents present in herbal plants.
  - Write the different targeted futuristic approaches and their potential of herbal plants.
  - Write the different pharmacological, nutraceutical properties shown by phytoconstituents present in herbal plants.

How the majority of people get healthcare internationally has changed significantly over the past century as a result of the mass manufacture of pharmaceuticals created through chemical synthesis. Despite this, for their primary care, many communities in poor nations still turn to conventional doctors and herbal remedies. Around 90% of individuals in Africa and 70% in India depend on traditional medicine to address their health requirements. In China, traditional medicine contributes to about 40% of healthcare services, with approximately 90% of general hospitals hosting dedicated departments for traditional medicine [5]. Using conventional medicine has spread outside underdeveloped countries over the past 20 years, as ethnobotanicals have become more popular and interest in natural cures has increased there. In the United States, conventional medicine was used by about 38% of adults and 12% of children in 2007. However conventional medicine is not just used in disadvantaged nations past 20 years. In wealthier nations, interest in natural remedies has skyrocketed along with a rise in ethnobotanical usage. In the year 2007, approximately 38% of adults and 12% of children in the United States utilized traditional medicine to fulfill their healthcare needs [10, 11].

People often opt for traditional medicine due to its broader accessibility, affordability, alignment with personal beliefs, alleviation of worries about synthetic drug side effects, fulfillment of the need for personalized healthcare, and alleviation of concerns regarding adverse effects. Rather than addressing life-threatening conditions, herbal remedies are frequently employed for managing chronic ailments and enhancing overall well-being. An increasing number of individuals are resorting to traditional solutions when modern medical treatments prove inadequate in effectively managing illnesses, particularly in cases of advanced cancer stages and newly emerging infectious diseases. Many people also believe that traditional remedies are organic, risk-free, and non-toxic. This does not always hold true, particularly when combining plants with over-the-counter drugs, prescription drugs, or other herbs, which is rather common [12, 13, 14, 15].

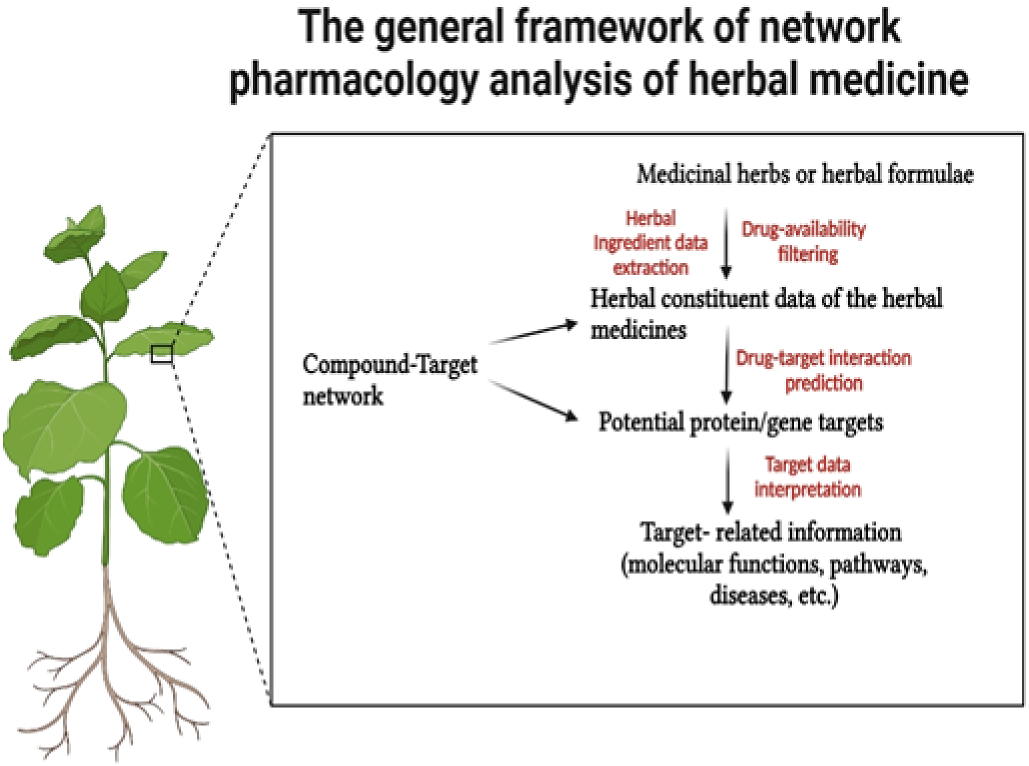

Figure 2: The General framework of network pharmacology analysis of herbal medicine

Plants contain a variety of compounds in large quantities. Most of the fragrant secondary compounds are phenols or their variations with added oxygen, like tannins [16, 17]. Many of these compounds exhibit antioxidant properties akin to those found in spices and plant antioxidants. Ethnobotanicals hold a crucial position in pharmacological investigation and the creation of innovative medicines, as plant constituents are directly harnessed for their healing attributes. Furthermore, they serve as essential building blocks for crafting medications or as models for biologically active molecules in the field of pharmacology [18]. Two hundred years ago, opium, a material collected from the seed pods of the *Papaver somniferum* poppy, was used to create morphine, the first pure molecule having pharmacological activity. This finding indicated that plant-derived remedies could be purified and administered in precise amounts, irrespective of their origin or age [19,16]. As a result of the discovery of penicillin, this strategy was improved. [18]. Commercial pharmaceutical products have significantly benefited from substances derived from plants, as well as other natural sources like fungi and marine microorganisms, or their comparable counterparts. Instances encompass digoxin, a heart stimulant extracted from foxglove (*Digitalis purpurea*); salicylic acid, a forerunner to aspirin acquired from willow bark (*Salix spp*.); reserpine, a medication for psychosis and hypertension sourced from Rauwolfia spp.; antibiotics like penicillin and erythromycin; and antimalarials such as quinine from Cinchona bark, and lipid-based compounds [8, 9, 18]. Over 60% of current or experimental cancer treatments rely on natural compounds. The 177 cancer drugs that have received global approval for usage are based on more than 70% of natural chemicals or their mimics, many of which have undergone combinatorial chemistry development. Three instances of plants employed as cancer remedies involve camptothecin from Camptotheca acuminata, popularly known as the "Chinese happy tree," utilized in the production of irinotecan and topotecan; as well as combretastatin sourced from the South African bush willow [20]. Additionally, 121 active chemicals derived from plants are used in approximately 25% of medications that are given globally [21]. Between 2005 and 2007, a total of 13 drugs containing natural compounds obtained approval in the United States. Presently, over 100 medications derived from natural ingredients are undergoing clinical investigations [18], However, merely 11% of the 252 drugs listed in the WHO essential medicine compilation are composed entirely of plant-based materials.[21].

Pharmacology nowadays faces a problem in describing and comprehending the variety of secondary metabolites, their mode of action either individually or naturally occurring combinations seen in plants. Discovering the plants that employed in traditional medical system around the world is an intriguing undertaking. You should also look into their phytochemistry and consider whether or not their secondary metabolites may have contributed to the observed pharmacological activity. Many conventional therapies, notably in Europe, have been modernized into licensed, clinically tested medications. Controlled clinical trials demonstrated that efficacy of a number of these plant medicines is employed in the production of irinotecan, topotecan, and the combretastati of the South African bush willow for their prescription in evidence-based medicine [22,23,24,25,26,27,28,29,30,31,32,33]. Extensive documents containing therapeutic details about various medicinal plants worldwide have been compiled and published. Significant among these documents are the ones produced by the German Commission E [34]. Also included in this list are the European Pharmacopoeia (Ph Eur) [35], the European Scientific Cooperative on Phytotherapy (ESCOP) for Phytotherapy [36,37], the WHO’s monographs on Herbal Medicines Products, and the European Medicines Agency's HMBC monographs. [27].

Table 1: The list of Popular Polyherbal Remedies used in Ayurveda, Unani, and Siddha Medicine to Treat Various Chronic Illnesses

S.No	Chronic diseases	Ayurveda	Unani	Siddha	References
1	Asthma (Respiratory condition)	**Bresol tablets created by The Himalaya Drug Company** consist of a blend of various herbal ingredients, including *long-leaf curcuma, sanctum arcae, Vasilis Adhatoda, Trikatu, Triphala, Cyperus rotundus, Embelia ribes, Elettaria cardamom, Cinnamomum tamala, Mesua ferrea, and Cinnamomum zeylanicum*	**(1) Safoof-E-Sana** Leaves of Senna plant, dried ginger, black salt (Vit lavana or vidam), haritake (*Terminalia chebula*) are all used in the Burge Sana recipe.) **(2) India's Pitkirya Hamdard Laboratories),** *Fumaria parviflora, Nardostachys jatamansi, Achillea millefolium, Rauwolfia serpentina, Acrous calamus, Lavandula stoechas, and Fumaria serpentina*	**Kaagamasi thailam** Milagu/Piper nigrum, Gingelly oil., Thipili (Piper longum), Chukku (Zingiber officinale), Manathakkali (Solanum nigrum)	[38,39,40,41,42].
2	Hypertension (High blood pressure)	**Artyl capsules** contain Bacopa monnieri (Brahmi) combined with zingiber	**Hypoff** consists of a mixture of Bombyx mori, Dorema	**Ratha azhutha nivarani** chooranam is a blend containing Coriandrum	[43,44,45]

		officinale (Sunthi).	ammoniacum, Nepeta hindostana, Rauwolfia serpentina, and Valerian officinalis**.**	sativum, Piper nigrum Cucumber cyminum, Zingiber officinale, Withania somnifera, Piper longum, Elattaria cardamomum, and Borneo camphora.	
3	Inflammatory joint disease (Rheumatoid Arthritis)	**Joint support supplement B** includes a blend of *Boswellia serrata, Glycyrrhiza glabra Commiphora wightii, Foeniculum vulgare, Alpinia galangal* and *Vitex negundo***.**	**Majoon Suranjan** comprises Lawsonia vulgaris, Ipomoea turpethum, Terminalia chebula, and Capparis spinosa, along with Apium graveolens, Colchicum luteum, Zingiber officinale, Foeniculum vulgare Plumbago zeylanica Convulvulus scammon, Ricinus communis and Cassia angustifolia. It also contains oils derived from Piper nigrum, Rosa damascena, Pyrethrum indicum, Coriandrum sativum, Verbascum Thapsus and Origanum	The organization called Kalpaamruthaa is identified as the **Indian Medical Practitioners Co-operative Pharmacy and Stores Limited (IMPCPS)**. Its formulation includes a blend of milk extract from Semecarpus anacardium nut, Emblica officinalis, and honey.	[46,47,48]

			vulgare		
4	Diabetes (Diabetes mellitus)	**(1) DIHAR Capsules** by Rajsa Pharmaceutical contain botanical ingredients including plant species *like S. dulcis, C. auriculata*, *C. longa, E. officinalis*, *G. sylvestre, M. charantia*, *S. cumini*, *T. C. indica, cordifolia, and T. foenum-graecum* **(2) MADHUSAN CHURNA62** Powder from Sanatan Ayurvedrashram consists of a mixture of herbal components, which encompass *M. charantia G. sylvestre*, *E. jambolana*, *M. fragrans M. philippinensis M. azadirachta, P. marsupium, A. punjabinon, T. terrestris, T. cordifolia, C. arundinaceum, , P. nigrum, T. foenum graecum, and V. bhasma* [11]	**Qurs Tabasheer as** Tukhme Khurfa (seeds of Portulaca oleracea), Gule Surkh (flowers of Rosa damascena), Gulnar (flowers of Punica granatum), Tabasheer (dry exudate from the node of Bambusa arundinaria), and Tukhme Kahu (seeds of Lactuca sativa Linn) are included.	The herbal mixture called **"Atthippattaiyathi kasayam" is** composed of various components, including Salacia reticulata, Ficus recemosa, Cassia fistula, Cassia auriculata, Tamarindus indica, Terminalia arjuna, Madhuca longifolia, Aloe barbadensis, Phyllanthus reticulatus, Hemidesmus indicus, and Amaranthus tricolor. It also contains Piper nigrum, Piper longum, Zingiber officinale, Tinospora cordifolia, Cyperus rotundus, fragrant myristica, Spermacoce hispida, Syzygium aromaticum, and Ferula asafetida**.**	[49,50,51]
5	Migraine headache	Haritaki (*Terminalia chebula*), Amalaki (*Phyllanthus emblica*), Haridra (*Curcuma longa*), Bhunimba (*Andrographis*	**Shaqeeqa Capsule** comprises Ustukhuddus, Kishhiz khushk, and Filfil Siyah, all of which	The mixture called **Athimadhuram Sombu** Paal Kashayam includes Sombu (Foeniculum vulgare) and	[52,53,54]

		paniculata) and Nimba (*Azadirachta indica*) Bibhitaki (*Terminalia bellirica*) are the botanical ingredients present in the formulation known as Pathyashadangam Kwath. Also, Guduchi (Tinospora cordifolia) is part of the composition.	are different types of the Lavendula stoechas Linn. plant.	Adhimadhuram (Glycyrrhiza glabra).	

Table 2: Utilizing the Roots of Specific Medicinal Plants Indigenous to India for Biomedical Purposes

Sl. No	Name of the Plant	Plant Family	Medical Applications	References
1	*Senna* (*Cassia*) *auriculata*	Fabaceae	Asthma	[55]
2	*Saussurea lappa*	Asteraceae	bactericidal and anticonvulsant properties	[56,57]
3	*Picrorhiza kurroa*	Plantaginaceae	anti-neoplastic, anti-inflammatory, and renal toxicity	[58]
4	*Salacia oblonga*	Celastaceae	It exhibits nephroproteive and antioxidant activity, and has been used to treat obesity, itch, rheumatism, and gonorrhoea.	[59,60,61,62]
5	*Valeriana wallichii*	Valerianceae	Properties that include countering Parkinson's symptoms, reducing inflammation, antioxidative effects, enhancing sleep quality, and adjusting brain monoamine levels.	[63,64,65]
6	*Berberis asiatica {Indian Barberry)*	Berberidaceae	antipyretic, antiseptic, and Blood cleansing qualities. treatment for haemorrhoids, stomach and duodenal ulcers, and conjunctivitis.	[66,67]
7	*Acorus calamus* (sweet flag, muskrat root)	Araceae	Improvement of speech and memory, kidney stone treatment, anti-allergic, anti-convulsant, anti-candida	[68,69,70,71]

8	*Cyperus rotundus* (purple nut sedge, coco grass)	Cyperaceae	Properties encompassing antioxidative, liver-protective, toxin-neutralizing, and diabetes-fighting effects.	[72,73,74,75,76]

Table 3: Utilizing the Leaves of Specific Medicinal Plants Indigenous to India for Medical Purposes

Sl. No	Plant	Family	Therapeutic Use	References
1	Sweet hibiscus *(Abelmoschus Manihot)*	Malvaceae	Antioxidative properties and anti-inflammatory	[77]
2	*Abutilon indicum* (Monkry bush)	Malvaceae	Apart from its application as an eyewash and mouthwash for addressing toothaches, sore gums, and treating gonorrhea, it also displays hypoglycemic and liver-protective attributes. It holds antibacterial and anticancer properties, showcases catalytic activity, and functions as an antioxidant.	[78,79,80, 81,82,83]
3	*Datura Metel* (Thorn apple)	Solanaceae	antimicrobial activity (Microbe-fighting capability)	[84]
4	*Solanum surattense* (Ringni)	Solanaceae	anti-inflammatory and Bacteria-inhibiting characteristics (anti-bacterial)	[85,86]
5	*Mucuna pruriens* (Monkey tamarind)	Fabaceae	managing sickle cell anaemia with an anti-sickling quality	[87]
6	*Senna* (*Cassia*)	Fabaceae	Conditions such as	[88,89]

	*auriculata (*Tanner's Cassia*)*		ulcers, skin disorders, leprosy, asthma, and the potential to counteract cancer.	
7	*Berberis Asiatica* (Indian barberry)	Berberidaceae	Safeguarding against DNA harm and countering hemolysis.	[90]

Table 4: Utilizing the Fruits of Specific Medicinal Plants Indigenous to India for Medical Purposes

Sl. No.	**Name of the plant**	**Family**	**Medical applications**	**References**
1	*Thespesia Populnea* (Indian tulip tree)	Malvaceae	Wound healing	[91]
2	*Datura metel* (Thorn apple)	*Solanaceae*	antioxidant and antibacterial properties	[92]
3	*Solanum Surattense* (Wild Eggplant)	Solanaceae	insulin-lowering impact	[93]
4	*Aegle marmelos* (Bael)	Rutaceae	Conditions such as jaundice, fever, asthma, hepatitis and tuberculosis., as well as to treat stomach problems and encourage animal lactation.	[94,95,96]
5	*Berberis asiatica* (Indian barberry)	Berberidaceae	characteristics that fight inflammation and free radicals, to combat hypertension, hypercholesterolemia, diabetes, and cancer	[97]

Table 5: Employing the Flowers and Seeds of Particular Medicinal Plants Native to India for Therapeutic Intentions

S. No.	Name of plant	Family	Medicinal use	References
1	Thorn apple (*Datura metel*) flower	Solanaceae	Seizures, gastrointestinal disturbance, sores, prolonged bronchial inflammation, cough, and respiratory issues like asthma. Additionally, it possesses properties that inhibit excessive cell growth, combat cancer, counteract microbes, alleviate itching and inflammation, and soothe skin irritation.	[98]
2	*Datura metel* seed (Thorn apple)	Solanaceae	healthy and diabetic rats induced with alloxan showed hypoglycemic activity,	[99]
4	*Sennaantiviral function* (*Cassia*) *auriculata* flower	Fabaceae	antiviral function	[100]
5	*Aegle marmelos* flower(Bael)	Rutaceae	Wounds healing	[101]
6	*Aegle marmelos* seed (Bael)	Rutaceae	Diuretic	[102]

Table 6: Utilizing the Stem, Bark, and Tuber of Specific Medicinal Plants Native to India for Therapeutic Purposes

S. No.	Name of plant	Family	Medicinal uses	References
1	Sunset hibiscus (*Abelmoschus Maniho))* stem	Malvaceae	Inflammation reduction	[77]
2	*Thespesia populnea* bark (Indian tulip tree)	Malvaceae	Management of Alzheimer's disease	[103]
3	Tanner's cassia *Senna* (*Cassia auriculata*) bark	Fabaceae	Conditions involving throat inflammation (pharyngitis), diabetes management, and eye-related issues.	[88]

4	Indian barberry (*Berberis* asiatica) stem	Berberidaceae	Efficient against both *V. cholerae* 01 and *V. cholerae* non 01, displaying antimicrobial attributes.	[104]
5	Purple nutsedge (*Cyperus rotundus*) tuber	Cyperaceae	Wound healing	[105]

Table 7: The Bioactive Components Extracted from Diverse Medicinal Plants in India and their Corresponding Therapeutic Applications

Sl. No	Name of plant	Plant part	Active Compounds	Application	References
1	Sunset hibiscus (*Abelmoschus Manihot*)	Manihot flower	Hyperin, hibifolin, quatercetin, isoquatercetin, and myricetin	Having properties that counter seizures, inflammation, bacterial infections, oxidative stress, protect the heart, and safeguard the nervous system.	[106]
2	*Abutilon indicum* (Country mallow)	fruit	14-methyl pentadecanoic acid methyl ester	Anti-inflammatory action	[107]
3	*Thespesia populnea* (Indian tulip tree)	seed	palmitic acid	Pain-relieving, inflammation-reducing	[108]
4	*Acorus calamus* (Sweet flag)	rhizome	alpha (α)-asarone	Anti-cancer properties and strategies for preventing chemotherapy-induced effects.	[109]
5	*Mucuna pruriens* (Monkey;s tamarind)	seed	Levodopa	Conditions such as male infertility, rheumatoid arthritis, diabetes, the aging process, and mental health concerns.	[110]

6	*Scoparia dulcis* (goatweed)	whole plant	hydroxamic acid	Fighting against fungi and bacteria	[111]
7	*Gymnema sylvestre* (Australian cowplant)	leaves	gymnemic acid	Reducing inflammation, serving as a sweetener, and relating to diabetes.	[112]
8	*Averrhoa bilimbi* (Cucumber tree)	fruit	Quercetin	Reducing inflammation and exhibiting antioxidant properties.	[113]
9	*Aegle marmelos* (Bael)	leaves	Eugenol	Combating inflammation and providing antioxidant benefits.	[114]
10	*Vitex negundo* (Chinese chaste tree)	seeds	Vitedoamine	Actions that reduce inflammation	[115]

II. MAJOR BIOACTIVE COMPOUNDS AND THEIR MOLECULAR MECHANISM

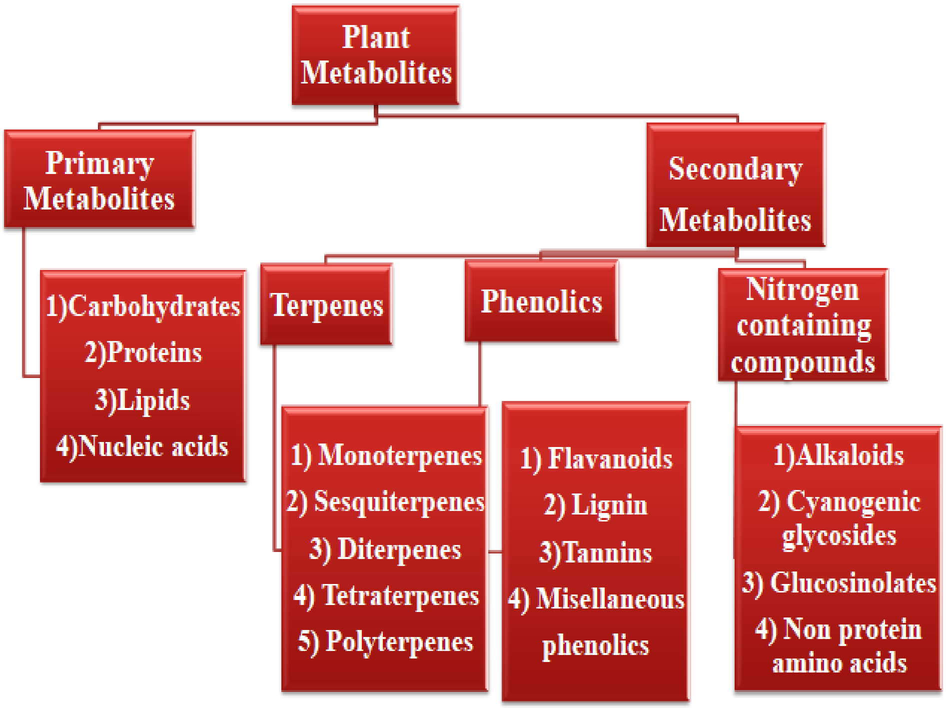

Figure 3: Classification of Phytochemicals

1. Molecular Basis of Various Medicinal Plants' Bioactive Substances and their Potential to Treat Certain Diseases and Ailments

- **CVDs (Cardiovascular Disease):** CVDs are frequently linked to heart and blood vessel diseases via persistent inflammation. 17.9 million individuals worldwide pass away from cardiovascular diseases each year, making up 31% of all fatalities [116]. Hypertension is a substantial contributor to the development of new CVDs and their consequences. As per Kim et al's research, the peel of citrus unshiu contains both the contracting agent synephrine and the anti-contracting element nobiletin, resulting in the plant displaying an abnormal pattern of vasoconstriction [117].

- **Diabetes:** Diabetes is a long-term metabolic disorder that, when blood sugar levels rise, can have a negative effect on the heart, blood vessels, eyes, kidneys, and nerves.he prevalent form is Type 2 diabetes. which arises from either insufficient insulin production or the body's reduced responsiveness to it [118]. In order to find and describe novel compounds with anti-diabetic action, constant attempts are made due to the unfavourable side effects of the currently prescribed anti-diabetic medications. [119,120]. In this particular research paper, Yang and coauthors illustrated that an alkaline extract derived from the fruiting body of *Amillariella mellea*, specifically its polysaccharide-rich portion, reduced fasting blood glucose levels in mice afflicted with type 2 diabetes. Additionally, it improved glucose intolerance and reduced insulin resistance in these mice [121].

- **Neurodegenerative Diseases:** Nerve cell death, evident in disorders viz Alzheimer's disease, Parkinson's disease, and multiple sclerosis, stems from inflammatory processes, changes in mitochondria, and increased oxidative stress [122,123]. Researchers believe that Octadecaneuropeptide (ODN), a naturally occurring substance in the body, has the potential to prompt the differentiation of N2a cells. This is achieved by activating a signaling pathway composed of protein kinase A (PKA), phospholipase C (PLC), protein kinase C (PKC), mitogen-activated protein kinase kinase (MEK), and extracellular signal-regulated kinase [123].

- **Osteoporosis:** The prospect of identifying new compounds with the potential to counter osteoporosis is highly promising, considering that osteoporosis is a prevalent bone condition characterized by an imbalance between excessive bone resorption and insufficient bone formation. [124,125,126,127]. Yodthong and colleagues found that L-quebrachitol prompted the generation of bone morphogenetic protein-2 (BMP-2) and influenced the activities of runt-related transcription factor-2 (Runx2), mitogen-activated protein kinase (MAPK), and the Wnt/-catenin signaling pathway. These effects encouraged the development, differentiation, and mineralization of pre-osteoblastic MC3T3-E1 cells [128]. An exclusive element called tetrahydroxystilbene glucoside found in the herbal remedy Radix Polygoni Multiflori was identified to trigger the PI3K/Akt pathway. This activation contributed to the proliferation and differentiation of MC3T3-E1 cells. The potential of tetrahydroxystilbene glucoside as an osteoporosis treatment is linked to its influence on the expression of osteoprotegerin (OPG), nuclear factor-B ligand (RANKL), macrophage colony-stimulating factor (M-CSF), and other related factors. [129].

- **Cancer:** Wei and colleagues indicated thepolysaccharide sourced from *Radix Astragali* induced a shift in macrophage polarization to M1 through the notch signaling system. This change enhanced macrophage cytotoxicity against cancer cells and led to decreased tumor volume and weight in vivo. Additionally, Ye et al. found that the wingless-type MMTV integration site family (Wnt)/-catenin signaling pathway hindered the anti-colorectal cancer effectiveness of 4-hydroxywithanolide E from Physalis peruviana, both in laboratory settings and within living organisms [131].

Table 8: Common Plant-Based Foods with Their Biological Functions and Bioactive Components

Food item	Active compound	Functions	Reference
Cauliflower, onions, garlic, broccoli, Brussels sprouts	Isothiocyanates, Diallyl sulphides and glucosinolates.	Cancer-fighting, immune system regulation, antimicrobial activity, and detoxification	[132,133]
Wheat (*Triticum aestivum*)	Immunopeptides obtained from wheat gluten	Enhanced natural killer cell function	[134]
Oats, whole grains, and fresh fruit with skin	Consumable Fiber	Reduction in lipid levels	[135]
Vegetables, tea, fresh fruits, red wine and Grapes	Polyphenols and Isoflavonoids	Antioxidative characteristics, reduction in lipid levels, immune-modulation capabilities, anti-osteoporosis potential, and anti-cancer properties	[136,137,138]
Soy products made from soy, cabbage, legumes, tea and Flaxseed	Phytoestrogens (Daidzein, Genistein)	Cancer-fighting, bone health-promoting, growth-inhibiting, and estrogen-reducing.	[139,140]
Coconut	Plant sterols within triglyceride molecules	Pain-relieving, arthritis-fighting, bacteria-inhibiting, fever-reducing, diarrhea-controlling, blood sugar-lowering. Worm-expelling, inflammation-reducing, pain-blocking, free radical-fighting,	[141,142,143,144]

		fungus-fighting, microbe-inhibiting, tumor-combating. Benefits related to heart health, epilepsy management, cell toxicity reduction, liver safeguarding, blood vessel dilation, kidney protection, and bone density preservation.	
Seeds, nuts, and Plant oil	Tocotrienols, tocopherols and Phytosterols	Reduction of lipid levels, regulation of the immune system, and protection against oxidative stress.	[145,146]
Corn, squash, Oranges, papaya, vegetables, carrots, green leafy and red palm oil	Carotenoids	Immune-boosting antioxidants.	[147]
Green vegetables (leafy)	Lutein	Age-Related Macular Degeneration is less common.	[148]
Vulgar Chlorella	Peptide with molecular weight of 2e5 Kda	Enhancement of cellular immune reactions, blood cell production, and triggering of the monocyte-macrophage defense system.	[149]
Tomatoes	Lycopene	Cancer-fighting, growth-inhibiting.	[150]
Garlic	Allicin and Ajoene	Exhibits antibacterial and anticancer effects, holds antibiotic and antistatic characteristics, and reduces LDL cholesterol.	[151,152]

Table 9: Common Animals Food Sources: Bioactive Elements and their Purposes

Food Item	Bioactive Compound	Function	Reference
Milk	Protein Whey	Immune responses, particular and general,	[168,169]
milk products and fermented milk	Bioactive peptides combination: Glycomacropeptide with lactoferrin	Antimicrobial, Antiproliferative, and Immune System Boosting	[170]
Fermented Milk-Based Products	Probiotics	Modulators of gastrointestinal health, anti-cancer, anti-bacterial, anti-oxidative, and immunomodulators	[171]
Crassostrea gigas (Ocean oysters)	Peptide Hydrolysate from JCOE	Characteristics that hinder the growth of herpes viruses.	[172,173, 174]
Egg	Lysozyme, Phospholipids Ovalbumin, Ovomucin, Avidin and Ovotransferrin	Actions with the potential to combat microbes, regulate the immune system, prevent cancer, and influence blood pressure.	[175,176]
Meat	ACE-Inhibitory Peptides, fatty acids, peptides, vitamins, and minerals	Hypertension-Reducing and Antioxidant Activities	[177,178]
Fish	Lectins, Peptides, Proteins, Polysaccharides, Polyether, and Fatty Acids. Proteins	Immunomodulatory, antithrombotic, antidiabetic, anticancer, anti-oxidant, and antimicrobial activities	[179,180, 181]

III. FUTURISTIC APPROACHES OF PHYTOCONSTITUENTS

As update in September 2021, there were several futuristic approaches being explored in the field of phytoconstituents (bioactive compounds derived from plants) research. These approaches aim to harness the potential of phytoconstituents for various applications, including medicine, agriculture, and industry. Developments in this field might have occurred since then, so from the latest research for the most up-to-date information on phytoconstituents. Here are some futuristic approaches that were being explored:

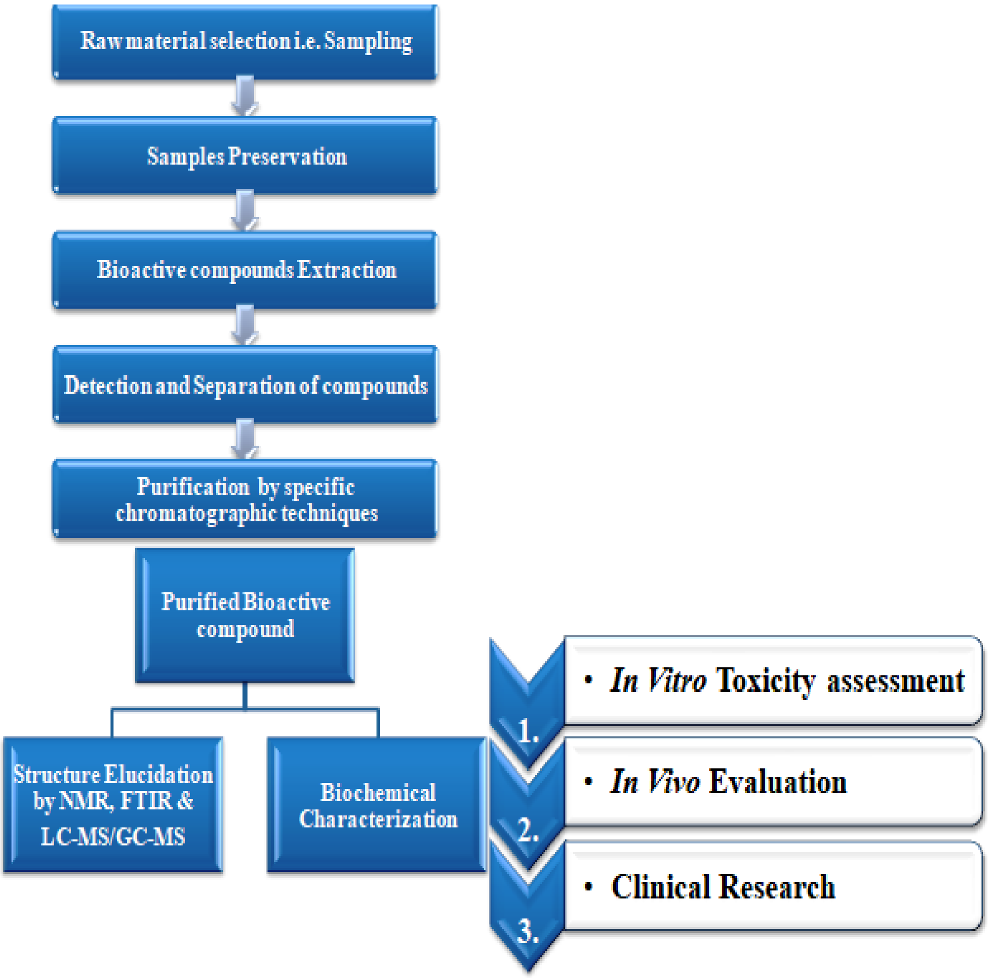

Figure 4: Bioactive compounds and their future therapeutic applications

1. Nanotechnology and Phytoconstituent

Nanotechnology encompasses the manipulation of substances at the nanoscale level. Scientists have been investigating methods to integrate phytoconstituents into nano-sized carriers. This approach aims to facilitate precise delivery of drugs to specific targets, increase the absorption of these compounds within the body, and elevate the overall effectiveness of treatments. By encapsulating phytoconstituents at the nanoscale, their vulnerability to deterioration is minimized, their ability to dissolve in solutions is heightened, and they can be gradually released in a controlled manner. This strategy enhances their suitability for addressing a range of illnesses [183].

In recent years, the integration of nanotechnology with phytoconstituents (bioactive compounds derived from plants) has opened up exciting possibilities for various applications in fields such as medicine, agriculture, energy, and environmental remediation. This convergence of nanotechnology and phytoconstituents offers numerous futuristic approaches with significant potential:

Table 10: Targeted futuristic approaches and their potential

Sr. No.	Futuristic approaches	Significant potential
1.	Nanoparticle delivery system	Phytoconstituents can be encapsulated within nanoparticles for targeted delivery to specific cells or tissues. This approach enhances the bioavailability and therapeutic efficacy of these compounds, reducing side effects and increasing their overall impact in areas like drug delivery and personalized medicine [184].
2.	Cancer therapeutics	Phytoconstituents have the potential to be incorporated into nano-sized formulations to enhance the treatment of cancer. These nanoparticles can precisely transport these bioactive compounds to cancerous cells, reducing harm to normal tissue while boosting the efficiency of therapies like chemotherapy [185].
3.	Agriculture and crop enhancement	Nanoencapsulation of phytoconstituents can lead to the development of smart agrochemicals. These nano-enabled formulations can improve the targeted delivery of pesticides, herbicides, and growth-promoting compounds to crops, minimizing environmental impact and maximizing yields [186].
4.	Nanobiosensor	Phytoconstituents can be integrated into nanosensor platforms for the detection of specific molecules or pathogens. This has applications in environmental monitoring, disease diagnosis, and food safety [187].
5.	Antimicrobial nanomaterial	Nanotechnology can help create novel antimicrobial materials incorporating phytoconstituents. These materials could be used for wound dressings, surface coatings, or even in water treatment systems to combat bacterial and fungal infections [188].
6.	Nanogel and drug release	Nanogels loaded with phytoconstituents can provide controlled and sustained drug release profiles. This is particularly useful for conditions requiring long-term treatment, such as chronic pain management [189].
7.	Energy storage and conversion	Nanostructured materials incorporating phytoconstituents might find applications in energy storage (e.g., batteries and supercapacitors) and energy conversion (e.g., solar cells and fuel cells) [190].
8.	Environmental Remediation	Phytoconstituent-loaded nanoparticles can be designed for efficient removal of pollutants from soil and water. These nanoparticles could assist in cleaning up contaminated environments and improving overall ecosystem health. [191]

9.	Personal care and cosmetics	Nanoencapsulation of phytoconstituents in skincare and cosmetic products could lead to enhanced product stability, controlled release, and improved efficacy [192].
10.	Anti-inflammatory and immunomodulator applications	Phytoconstituents with anti-inflammatory or immunomodulatory properties could be engineered into nanoparticles for more effective treatment of inflammatory diseases and autoimmune disorders [193].

It's crucial to acknowledge that while these strategies offer significant potential, there are obstacles linked to the application of nanotechnology and phytoconstituents. These challenges encompass regulatory factors, possible worries about toxicity, and the scalability of manufacturing processes [194]. Research and development in this interdisciplinary field are ongoing to harness the full potential of these futuristic approaches.

2. Phytoconstituents in Personalized Medicine

Advances in genomics and personalized medicine have paved the way for tailoring treatments to individual patients. Phytoconstituents, with their diverse bioactivities, could play a role in personalized medicine by targeting specific molecular pathways or genetic markers associated with diseases [195]. This method entails pinpointing suitable phytoconstituents for an individual patient by analyzing their genetic and molecular characteristics. Personalized medicine pertains to adapting medical care and health strategies according to an individual's distinct genetic composition, lifestyle, and related aspects. Integrating phytoconstituents into personalized medicine encompasses employing these natural elements to customize treatments and approaches for particular individuals [196]. Here are some ways in which phytoconstituents are being explored in personalized medicine:

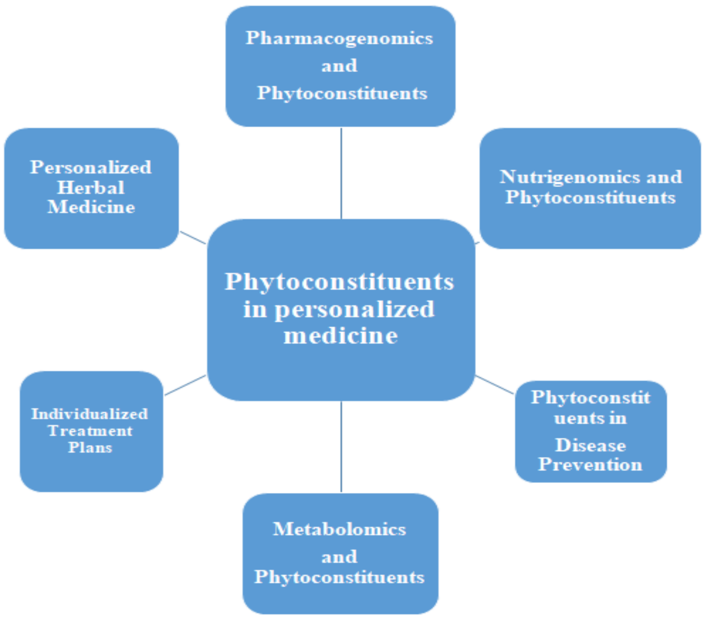

Figure 5: Scope of Phytoconstituent in Personalized Medicine [197]

It's important to note that while phytoconstituents hold great promise in personalized medicine, their use should be based on rigorous scientific research and clinical evidence. Healthcare practitioners should work collaboratively with patients to make informed decisions about incorporating phytoconstituents into personalized treatment strategies [198, 199]. Additionally, potential interactions between phytoconstituents and other medications should be carefully considered to ensure patient safety.

3. Synthetic Biology and Phytoconstituents Production

Synthetic biology involves designing and engineering biological systems for specific applications. Researchers are exploring ways to use synthetic biology techniques to engineer plants for enhanced phytoconstituent production. This could lead to the development of plants with optimized phytoconstituent profiles, making them more suitable for medicinal or industrial purposes [200].

4. Phytoconstituents in Agriculture and Pest Management

Phytoconstituents can have pesticidal properties that could be harnessed for sustainable pest management in agriculture. Research is ongoing to identify and develop phytoconstituents that effectively control pests while minimizing harm to beneficial organisms and the environment [201].

In the context of agriculture and pest management, phytoconstituents can have significant applications. Here are some examples of phytoconstituents and their roles in agriculture and pest managemen.t

- **Alkaloids**: Alkaloids are substances with nitrogen that frequently have strong physiological effects on people, animals, and insects. By disrupting the neurological systems of insects, several alkaloids function as natural pesticides. Nicotine from tobacco plants and pyrethrins from chrysanthemum flowers are two examples [201].

- **Terpenoids**: Terpenoids form a varied collection of substances responsible for the unique fragrances and tastes found in numerous plants. Several terpenoids, including essential oils, possess insect-repelling qualities. For instance, citronella oil deters mosquitoes, while neem oil hampers insect growth and disturbs their feeding behaviors [202].

- **Phenolic Compounds:** Phenolic compounds, encompassing phenolic acids, flavonoids, and tannins, exhibit both antioxidant and antimicrobial attributes. They have the capability to hinder the proliferation of pests and pathogens and play a role in bolstering a plant's immunity against diseases and herbivores [203].

- **Glycosides**: Glycosides are substances created by attaching a sugar molecule to a non-sugar component known as an aglycone. Certain glycosides, like rotenone and ryanodine, possess toxicity against insects and are employed as natural insecticides [204].

- **Lectins**: Lectins are proteins that can bind to carbohydrates. They play a role in plant defense by interfering with insect digestion and development. Lectins are often toxic to insects and can disrupt their feeding [205].

- **Saponins**: Saponins are glycosides that have a soap-like structure. They can disrupt cell membranes and have insecticidal properties. Saponins are often used as natural insecticides in organic farming [206].

- **Coumarins**: Coumarins are compounds that have anticoagulant and insecticidal properties. They can interfere with blood clotting in insects and disrupt their normal physiological processes [207].

- **Furanocoumarins**: Furanocoumarins are a type of coumarin that can cause photosensitivity in insects. When insects that have consumed furanocoumarin-containing plants are exposed to sunlight, they experience skin damage, leading to reduced feeding and survival [208].

- **Resins and Latex**: Some plants produce resins and latex that contain toxic compounds, which deter herbivores and insects. These compounds can interfere with insect feeding and act as physical barriers [209].

- **Allelochemicals**: Allelochemicals are compounds synthesized by plants that impact the growth and behavior of other organisms. These chemicals can exhibit allelopathic consequences on nearby plants, curtailing their growth and overall progress [210].

It is crucial to acknowledge that although phytoconstituents can possess pesticidal characteristics, their application in pest control demands thorough assessment to guarantee their efficacy, safety, and limited influence on unintended organisms and the ecosystem. Moreover, the concentration of these phytoconstituents can differ based on factors like plant type, cultivation circumstances, and the specific plant components employed.

5. Phytoconstituents for Neurological Disorders

Specific phytoconstituents have exhibited potential in early-stage research for their possible abilities to safeguard and rejuvenate the nervous system. Scientists are exploring their potential in addressing neurodegenerative conditions such as Alzheimer's and Parkinson's disease, in addition to supporting brain well-being and cognitive capabilities [211]. Below are several phytoconstituents that have been investigated for their potential impact on neurological disorders.

- **Curcumin:** Found in turmeric, curcumin has anti-inflammatory and antioxidant properties. It has been investigated for its potential to alleviate symptoms of neurodegenerative diseases like Alzheimer's and Parkinson's by reducing inflammation and oxidative stress [212].

- **Resveratrol:** Present in grapes, berries, and red wine, resveratrol has garnered attention for its possible neuroprotective properties. It is believed to shield brain cells from harm and has been proposed to exhibit beneficial effects on conditions such as Alzheimer's disease [213].

- **Ginkgo Biloba:** Utilized in traditional medicine for enhancing cognition, this botanical extract is thought to enhance blood circulation and possess antioxidant characteristics. These attributes could potentially contribute to improved cognitive function and offer advantages for conditions like dementia [214].

- **Bacopa Monnieri:** Employed in Ayurvedic medicine, this herb has been subject to exploration due to its potential for augmenting cognitive function and memory. Additionally, it could potentially exert neuroprotective effects [215].

- **Ashwagandha:** Another herb originating from Ayurvedic medicine, ashwagandha is recognized for its adaptogenic attributes and its potential to alleviate stress and anxiety. Certain studies propose that it might also offer neuroprotective benefits, making it potentially advantageous for neurodegenerative conditions [216].

- **Cannabidiol (CBD):** Obtained from the cannabis plant, CBD has garnered notice for its possible ability to relieve symptoms of epilepsy, anxiety, and other neurological disorders. Importantly, it does not induce the psychoactive effects linked to THC [217].

- **Ginseng:** The ginsenosides present in ginseng have been scrutinized for their potential to enhance cognition. Ginseng holds the potential to enhance memory and cognitive function [218].

- **L-DOPA from Mucuna Pruriens:** Mucuna pruriens provides a natural supply of L-DOPA, which serves as a precursor to dopamine. In treating Parkinson's disease, L-DOPA is employed to restore dopamine levels [219].

- **Huperzine A:** Huperzine A, obtained from the Chinese club moss plant, has been studied for its potential to enhance memory and cognitive capabilities. Its mechanism involves blocking the degradation of acetylcholine, a crucial neurotransmitter for memory and learning processes [220].

- **Polyphenols:** Polyphenols like epigallocatechin gallate (EGCG) from green tea and quercetin from fruits and vegetables, present in diverse plant sources, have demonstrated antioxidant and anti-inflammatory properties. These attributes could potentially contribute to the well-being of the nervous system [221].

6. Phytoconstituents in Cosmeceuticals

Phytoconstituents are being investigated for their potential in skincare and cosmetic products due to their antioxidant, anti-inflammatory, and anti-aging characteristics. Compounds from plants can be used in formulations for skincare, hair care, and other cosmetic uses [222].

Phytoconstituents are often used in various products, including cosmeceuticals, which are cosmetic products that claim to have medicinal or therapeutic benefits. Phytoconstituents can contribute to the efficacy of cosmeceuticals by providing antioxidant, anti-inflammatory, moisturizing, and other desirable properties [223]. Here are some common phytoconstituents found in cosmeceuticals and their potential benefits:

- **Polyphenols:** These compounds have strong antioxidant properties and help protect the skin from oxidative stress and environmental damage. Examples include flavonoids, tannins, and resveratrol, commonly found in green tea, grape seeds, and various berries [221].

- **Flavonoids:** In addition to their antioxidant properties, flavonoids can also possess attributes that combat inflammation and promote anti-aging effects. These compounds are frequently present in citrus fruits, chamomile, and licorice [224].

- **Carotenoids:** Carotenoids like beta-carotene and lycopene are known for their skin-protective effects. They contribute to skin health by reducing UV damage and supporting collagen production. Carotenoids are found in colorful fruits and vegetables like carrots, tomatoes, and sweet potatoes [226].

- **Terpenes and Essential Oils:** Chamomile oil is known for its skin benefits [227]. Essential fatty acids, such as omega-3 and omega-6, play a crucial role in preserving the skin's barrier function and preventing moisture loss. These fatty acids are commonly present in oils like flaxseed oil, evening primrose oil, and hemp seed oil [227].

- **Fatty Acids:** Preserving the skin's barrier function and preventing moisture loss necessitates essential fatty acids, with a particular focus on omega-3 and omega-6. These essential fatty acids are frequently present in oils such as flaxseed oil, evening primrose oil, and hemp seed oil [228].

- **Vitamins:** Antioxidant vitamins such as vitamin E (tocopherols) and vitamin C (ascorbic acid) play a significant role in safeguarding the skin against harm from free radicals and stimulating collagen production. These vitamins are frequently included in cosmeceutical products to enhance their formulations [229].

- **Enzymes:** Enzymes derived from plant sources, like bromelain from pineapple and papain from papaya, aid in exfoliating the skin by effectively breaking down dead skin cells. This process contributes to achieving a smoother and more even complexion [230].

- **Phytosterols**: These substances possess attributes that alleviate inflammation and provide hydration, contributing to the calming of irritated skin and the preservation of moisture. They are frequently present in plant-based oils like shea butter and avocado oil [231].

- **Saponins**: Saponins exhibit cleansing and foaming characteristics, rendering them valuable components in cleansers and shampoos. These compounds are present in plants such as soapwort and quinoa [231, 232].

- **Aloe Vera**: Aloe vera includes polysaccharides known for their moisturizing and wound-healing attributes. It is frequently employed to provide relief to sunburned or irritated skin.

7. Phytoconstituents as Natural Preservatives

The food and beverage sector is actively exploring natural alternatives to synthetic preservatives. Phytoconstituents possessing antimicrobial and antioxidant attributes are being considered to prolong the shelf life of food items while upholding their safety and excellence. These phytoconstituents function as natural preservatives across diverse domains, such as food, cosmetics, and pharmaceuticals. By providing antimicrobial, antioxidant, and other protective characteristics, phytoconstituents contribute to extending product shelf life and averting deterioration [233]. Here are some examples of phytoconstituents that have been studied for their preservative properties:

- **Phenolic Compounds**: Flavonoids, phenolic acids, and tannins are phenolic compounds acknowledged for their antioxidant and antibacterial attributes. They play a role in inhibiting lipid oxidation and microbial proliferation in both food and cosmetic products. Some instances of phenolic compounds encompass quercetin, catechins, and ellagic acid [234].

- **Essential Oils**: Essential oils are volatile substances obtained from plants, known for their abundance in terpenoids and phenolic compounds. They showcase potent antimicrobial attributes and can be applied to impede the proliferation of bacteria, fungi, and molds. Essential oils such as oregano, thyme, and rosemary have been under scrutiny for their potential as preservatives [235].

- **Alkaloids**: Alkaloids are nitrogen-containing compounds present in plants, frequently carrying notable antimicrobial characteristics. Notable instances include berberine, derived from plants like goldenseal and barberry, as well as caffeine, found in coffee beans [236].

- **Saponins**: Saponins are glycosides known for their foaming and emulsifying attributes. They also possess antimicrobial capabilities, making them suitable as natural preservatives. The preservative potential of saponins from plants like soapwort and ginseng has been a subject of research [237].

- **Polyphenols**: Polyphenols constitute a diverse category of phytochemicals present in numerous fruits, vegetables, and beverages such as tea and wine. Their antioxidant and antimicrobial characteristics render them promising candidates as natural preservatives [238].

- **Carotenoids**: Carotenoids are pigments accountable for the red, orange, and yellow hues in various plants. Possessing antioxidant attributes, they can serve to shield products against oxidative deterioration.

- **Terpenoids**: Terpenoids comprise a substantial group of compounds present in essential oils and plant resins. With inherent antimicrobial characteristics, they can be effective in deterring microbial growth and averting spoilage [239].

- **Lectins**: Lectins are proteins that bind to carbohydrates and are present in plants. Certain lectins showcase antimicrobial qualities and have been investigated for their potential as natural preservatives [240].

8. Phytoconstituents for Sustainable Energy Production

Some plants contain phytoconstituents that can be used for biofuel production. Researchers are exploring the potential of these compounds as renewable sources of energy, contributing to the development of sustainable and environmentally friendly energy solutions [241].

While plants are not typically used as a primary source of energy like fossil fuels or renewable sources (e.g., solar, wind, hydro), certain phytoconstituents can play a role in energy-related processes [242]. Here are a few examples:

- **Biofuels and Biodiesel**: Some plants contain oils that can be extracted and processed into biofuels or biodiesel. Oil-rich crops such as soybeans, sunflowers, and palm can be cultivated to produce biofuels that can be used as a substitute for fossil fuels [243].

- **Ethanol Production**: Ethanol, a biofuel, can be generated through the fermentation of sugars or starches obtained from plants. Crops like corn, sugarcane, and cellulose-rich plants can serve as sources for ethanol production [244].

- **Biogas Production**: Biogas is produced via the anaerobic digestion of organic matter, encompassing materials such as crop residues, food waste, and sewage. The primary constituent of biogas is methane, which can be harnessed as a renewable energy resource [245].

- **Plant-Microbial Fuel Cells**: Certain plants have been studied in the context of microbial fuel cells, where microorganisms in the soil interact with plant roots to generate electricity. This technology is still in its experimental stages but holds potential for sustainable energy production [245].

- **Hydrogen Production**: Some plants contain enzymes or natural compounds that can facilitate the production of hydrogen gas through biochemical processes. Hydrogen is a clean and versatile energy carrier [246].

- **Photosynthesis and Solar Energy**: While not directly used for energy production, plants are central to the process of photosynthesis, which converts solar energy into chemical energy. Understanding and harnessing the principles of photosynthesis could inspire advancements in solar energy technologies [247].

9. Phytoconstituents and Health of Gut

The gut the microbiome significantly impacts general well-being, and specific phytoconstituents have been examined for their prebiotic and probiotic influences. These compounds potentially enhance gut health by stimulating the growth of advantageous gut bacteria and adjusting the composition of the gut microbiota.

These innovative strategies showcase the extensive possibilities of phytoconstituents across diverse domains. Nonetheless, it's essential to recognize that turning these concepts into practical implementations usually demands thorough research, comprehensive testing, and regulatory clearance. For the latest advancements in this swiftly evolving realm, it's advisable to consult the most recent scientific literature [248].

Phytoconstituents can have a significant impact on gut health due to their interactions with the digestive system and the gut microbiota. Here are some ways in which phytoconstituents can influence gut health:

- **Fiber:** Fiber, a prominent phytonutrient, is prevalent in fruits, vegetables, whole grains, and legumes. Unlike being digested in the small intestine, it travels to the colon where it serves as a nourishment source for beneficial gut bacteria. This bacterial digestion yields short-chain fatty acids (SCFAs) like butyrate, acetate, and propionate. SCFAs are vital for maintaining gut lining health, reinforcing the immune system, and reducing inflammation [249].

- **Polyphenols:** Polyphenols, another subset of phytoconstituents, are present in diverse plant-based foods such as berries, tea, coffee, dark chocolate, and numerous fruits and vegetables. These compounds possess both antioxidant and anti-inflammatory attributes, which play a role in bolstering gut health by mitigating oxidative stress and inflammation in the digestive system. Certain polyphenols additionally exhibit prebiotic effects, encouraging the proliferation of beneficial gut bacteria [250].

- **Probiotics and Prebiotics:** Several plants possess compounds functioning as prebiotics, furnishing nourishment for advantageous gut bacteria. Moreover, specific plant-derived foods, including fermented products like yogurt, kefir, sauerkraut, and kimchi, house live beneficial bacteria termed probiotics. These probiotics contribute to reestablishing and sustaining a harmonious gut microbiota balance [251].

- **Glycosides:** Glycosides are plant-based substances capable of inducing diverse physiological outcomes. As an illustration, anthraquinone glycosides present in particular herbs have been employed as natural laxatives, facilitating bowel movements and alleviating constipation.

- **Mucilage:** Mucilage is a viscous material discovered in certain plants like flaxseeds and okra. Ingesting mucilage can offer a calming and safeguarding influence on the gastrointestinal tract, potentially assisting in the relief of conditions like gastritis and acid reflux [252].

10. Anti-Microbial Compounds

Certain phytoconstituents, including specific alkaloids and flavonoids, have been identified for their antimicrobial traits. These compounds could contribute to upholding a balanced gut bacteria ecosystem by restraining the growth of detrimental microorganisms.

It's crucial to recognize that while phytoconstituents can play a role in enhancing gut health, individual reactions can differ. Variables such as genetics, overall dietary habits, and the existing state of the gut microbiota can influence how phytoconstituents affect gut well-being. Generally, a well-rounded and diverse diet that includes an assortment of plant-based foods is advisable to promote optimal gut health [253].

Prior to making substantial alterations to your diet or incorporating herbal remedies, it's recommended to seek guidance from a healthcare professional, particularly if you have particular gut-related worries or existing medical conditions.

IV. CONCLUSION

The majority of people get healthcare internationally has changed significantly over the past century as a result of the mass manufacture of pharmaceuticals created through chemical synthesis. Despite this, for their primary care, many communities in poor nations still turn to conventional doctors and herbal remedies. People often opt for traditional medicine due to its broader accessibility, affordability, alignment with personal beliefs, alleviation of worries about synthetic drug side effects, fulfillment of the need for personalized healthcare, and alleviation of concerns regarding adverse effects. Rather than addressing life-threatening conditions, herbal remedies are frequently employed for managing chronic ailments and enhancing overall well-being. The herbal plants are having a lot of phytoconstituents are present such as flavonoid, alkaloid, terpenoid, tannins, saponins, phenolic compounds which are used in wide range due to their various pharmacological properties in treatment of various diseases, their nutraceutical application, in agriculture as pesticides and food science etc. These herbal medicines are used in futuristic trends due to their novel medicinal drug approaches.

Consent for Publication

None

Conflict of Interest

None

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